

# Roost selection by the lesser long-eared bat, *Nyctophilus geoffroyi*, and the greater long-eared bat, *N. major* (Chiroptera: Vespertilionidae) in *Banksia* woodlands

D J Hosken

Department of Zoology, University of Western Australia, Nedlands WA 6907

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## Abstract

Radiotelemetry was used to track eight *Nyctophilus geoffroyi* and three *N. major* to roosts in *Banksia* woodland, on the Swan Coastal Plain south of Perth, intermittently between January and August 1995. All roosts were found in large or dead trees and bats were never captured more than 1.2 km from their roosts. Twenty two roosts were identified in six species of trees. Both species of bat changed roosts regularly, and were always found to roost alone. *N. geoffroyi* showed a strong preference for roosts in dead *Banksia* trees, although they also roosted in *Melaleuca* trees during storms. The differential use of the two tree species by *N. geoffroyi* may relate to water harvesting differences between the two types of tree, and to temperature differences between roosts found in each tree species; roosts in *Melaleuca* trees stay dry but are much colder than roosts in *Banksia* trees. *N. major* were tracked to *Eucalyptus rudis* and *Melaleuca raphiophylla* trees, but only one roost was actually located. Stands of forest containing dead trees may be necessary for the persistence of both species.

## Introduction

Roost sites are a critical resource for bats, providing shelter, protection, mating and hibernation sites (Kunz 1982). It has been argued that roost availability is, or may become, a limiting resource for many bat species (Taylor & Savva 1988).

While a number of studies have investigated the use of roosts by eastern Australian bats (e.g. Taylor & Savva 1988; Lunney *et al.* 1988, 1995), little is known about the roosts used by forest bats in Western Australia. This is particularly true for *Nyctophilus geoffroyi*, for which no detailed account of roost use has been published.

The lesser long-eared bat, *N. geoffroyi* is a small (5.5–8.0 g) vespertilionid bat. Its diet includes lepidopterans, coleopterans, hymenopterans, dipterans and orthopterans (Vestjens & Hall 1977). *N. geoffroyi* is known to forage by gleaning and is able to exploit prey generated noise, including acoustic signals, to locate prey (Grant 1991; Hosken *et al.* 1994). These bats are found throughout Australia, with the exception of Cape York Peninsula (Hall & Richards 1979), although their taxonomy may be more complex than is currently recognised (N L McKenzie *pers. comm.*; H Parnaby *pers. comm.*). *N. geoffroyi* is reported to roost in trees, in hollows and under bark, and also roosts in buildings (Lumsden & Bennett 1995; Reardon & Flavel 1991). These bats usually roost alone (Lumsden & Bennett 1995; L Lumsden *pers. comm.*) or in small maternity colonies of generally less than 30 individuals, although one colony of about 200 *N. geoffroyi* has been reported (Reardon & Flavel 1987).

Less is known about the biology of *N. major* (also known as *N. timoriensis*). It is widely distributed but

uncommon throughout southern Australia, although the presence of distinct geographic forms indicate that a species complex may be present (Parnaby 1995). It is about twice the size of *N. geoffroyi*, weighing between about 11 to 20 grams. *N. major* is thought to roost alone or in pairs in tree hollows, but even this is uncertain (Richards 1991).

This study primarily aimed to investigate roost selection by *N. geoffroyi* in *Banksia* woodlands on the Swan Coastal Plain south of Perth. In addition, the fortuitous capture of three *N. major* provided an opportunity to investigate roosting in this species.

## Methods

This study was carried out at the Harry Waring Marsupial Reserve, Wattleup (approximately 32° 15' S, 115° 50' E) from January to August 1995. The reserve is small, approximately 250 hectares, and is predominantly low open woodland on Bibra Sands. It includes a mixture of *Eucalyptus rudis*, *E. gomphocephala*, *E. marginata* and *Melaleuca preissiana* and *M. raphiophylla*, but is dominated by *Banksia* woodlands (*Banksia attenuata* and *B. menziesii*), with a variable understory (for further description see Hosken & O'Shea 1994).

Bats were captured in mist-nets set in woodlands and were fitted with small radio-transmitters (Titley Electronics) with 8–12 cm flexible wire antennas and an expected battery life of about 8 days. Transmitters weighed between 0.7 and 1.1 g, which represents 11–17% of the mean body weight of the *N. geoffroyi* captured during this study (less than 9% of the body weight of *N. major*). This is less than the weight of the two foetuses that female *N. geoffroyi* carry during late pregnancy (unpublished data), and is proportionally less than the mass of transmitters carried by bats in other studies (e.g. Lunney *et al.* 1995; 12–19% of body mass). In trials with

three captive *N. geoffroyi*, transmitters did not appear to adversely affect the bats behaviour or mobility, and transmitters were shed in 6–15 days. Bats fitted with transmitters in this study did not lose weight over the 4–6 days that they carried transmitters, which also indicates that transmitters had no obvious adverse effects.

Transmitters were attached to the dorsal fur between the shoulder blades using rapid-set cyanoacrylate glue, with the antenna projecting posteriorly. Diurnal roosts were then located by radiotelemetry, with radio-signals from transmitters received using a receiver and directional 'h-frame' antenna (Biotelemetry, SA). Roost location was usually confirmed by sighting the bat or the transmitter antenna.

The following roost characteristics were recorded; tree species and whether it was alive or dead, the diameter at breast height (DBH), the roost height, the direction it faced and distance from last sighting of the bat. Distances were either measured directly or calculated using a map marked with 100 x 100m grids. Later, when roosts were vacant, temperature fluctuations inside and outside each roost were recorded during the course of a day. Each roost was visited once each hour from 9am till 5pm and the temperature in the roost ( $T_r$ ) and the ambient temperature ( $T_a$ ) just outside the roost were recorded using a Radio Spares type-K thermocouple meter and thermocouple.

Statistics were mainly performed using the Statview + SE statistical package, and data are presented as means with  $\pm$  standard error, unless stated otherwise.

## Results

Eight (four male, four female) *N. geoffroyi* and three (two male, one female) *N. major* were tracked over a total of 42 days during 1995. *N. major* were tracked in January and February, while the *N. geoffroyi* were tracked intermittently from April to August. During this time *N. geoffroyi* begins mating; the sperm is stored until about October, when pregnancy is initiated (Hosken unpublished data). The *N. major* were each tracked for four days and nights, and six roost trees were identified. Two *N. geoffroyi* lost transmitters and one was killed by an owl on the first night. The other five were tracked for

Table 1

The tree species in which bats were found to roost. (Dead or alive refers to the tree)

Tree spp	<i>N. major</i>	<i>N. geoffroyi</i>
<i>Banksia attenuata</i>	0	6 (all dead)*
<i>Banksia menziesii</i>	0	2 (all dead)*
<i>Eucalyptus rudis</i>	3 (2 alive but burnt, 1 dead)	1 (dead)
<i>Eucalyptus marginata</i>	0	1 (dead)
<i>Melaleuca pressiani</i>	0	4 (all alive)
<i>Melaleuca raphiophylla</i>	3 (all alive)	0

\* Two other roosts were located in dead banksia; however, the species could not be determined.

Table 2

The diameter at breast height (DBH) and roost height of trees in which *N. geoffroyi* roosts were found (mean  $\pm$  SE).

Tree	DBH	roost height
<i>Banksia attenuata</i>	0.38m ( $\pm$ 0.1)	1.85m ( $\pm$ 0.55)
<i>Banksia menziesii</i>	0.25m ( $\pm$ 0.13)	0.85m ( $\pm$ 0.15)
<i>Eucalyptus rudis</i>	0.38m	2.9m
<i>Eucalyptus marginata</i>	1.19m	5.1m
<i>Melaleuca pressiani</i>	0.9m ( $\pm$ 0.1)	2.13m ( $\pm$ 0.52)

four to six days each, allowing 15 roosts to be identified. An additional *N. geoffroyi* roost was found while searching for a *N. major*.

*N. geoffroyi* changed roosts frequently (mean number of days that each roost was occupied was  $1.13 \pm 0.15$ ) and were predominantly found roosting in dead *Banksia* trees, under bark that had come away from the tree trunk to form a loose fitting sleeve. (Fig 1, Table 1). *N. major* were found to roost in Paperbark trees or Flooded gums and occupied each tree for  $1.83 \pm 0.48$  days.

*N. geoffroyi* tended to move roosts on a daily basis, except for one bat which was found in the same roost on 3 consecutive days during a storm; this roost was in a Paperbark tree (*Melaleuca preissiana*). The only times these trees were used as roosts by *N. geoffroyi* was during storms or when it was raining (4 bats on 6 days; 6 out of 6 occasions; sign test  $P = 0.016$ ). Roosts were always under bark. Interestingly, these were the only live trees in which *N. geoffroyi* roosts were found, and no bats were found to be roosting in *Banksia* trees when there had been rain overnight. *N. geoffroyi* were located in roosts on 16 occasions and were always alone. Roosts tended to be close to the ground ( $1.93 \pm 0.36$ m), but average roost height varied with the species of tree as did the DBH of trees in which bats roosted (Table 2). The majority of roosts were either on the north or west face of trees or were in direct afternoon sun (9 of 14; note that the roost used on three consecutive days was only counted once)

Only one of six *N. major* roosts was located. This was in a fissure within a branch of a burnt-out, dead *E. rudis*. This branch was shared with an unmarked *N. geoffroyi*, although these bats were not in the same fissure. Other roosts, in large *Melaleuca raphiophylla* trees, were inaccessible, but two *N. major* were located in the same trees for three and four consecutive days respectively.

While *N. geoffroyi* were sometimes captured a substantial distance from where they were subsequently found to roost (850–1200 m maximum), the roosts used by an individual were generally much closer to each other (mean distance roost to roost =  $194 \pm 57$  m) suggesting some area fidelity (Fig 2). A Student's t-test comparison of the mean distance between the point of capture and the roost location on the day after capture, and the mean distances moved between roosts, revealed that the difference was statistically significant (unpaired  $t_{15}$  value = 3.33,  $P = 0.0046$ ). There was no significant difference between the sexes in the distances moved between roosts or in the distances between point of capture and subsequent roost location (two tailed unpaired Student's t-test comparison,  $P > 0.32$  for each comparison).



Figure 1. Typical *N. geoffroyi* roost found in dead *Banksia* tree. Roost (marked with arrow) was 0.8 m above ground. Width of central branch was 0.32 m.

There was a significant and positive relationship between  $T_a$  and  $T_r$  in both *Banksia* and *Melaleuca* trees ( $r^2=0.78$ ,  $f_{2,54} = 199.6$ ,  $p = 0.0001$  and  $r^2 = 0.81$ ,  $f_{2,13} = 55.9$ ,  $P = 0.0001$  respectively). However, the slope of the line describing the relationship between  $T_a$  and  $T_r$  for *Banksia* roosts was significantly greater than that for roosts in *Melaleuca* trees (test of slopes:  $t_{67} = 5.6$ ,  $P < 0.001$ ) and at  $T_a$ s above about  $16^\circ\text{C}$  the temperatures in *Banksia* roosts was always greater than those in *Melaleuca*. In addition, in *Banksia* trees  $T_r$  typically approached  $T_a$  by about  $1200$  and by the time final temperature measurements were taken (between  $1600$  and  $1700$ ) five of six roosts in *Banksia* had temperatures that exceeded ambient by about  $1.0^\circ\text{C}$  (range  $0.3\text{--}1.7^\circ\text{C}$ ; Fig 3). The temperature of roosts in *Melaleuca* trees never exceeded  $T_a$  during the measurement periods (Fig 3).

### Discussion

*Nyctophilus geoffroyi* roost in trees and change roost regularly. This habit has been recorded in a number of other Australian forest bats (L Lumsden, *pers. comm.*; Lunney *et al.* 1988, 1995) and is consistent with the proposal that roost fidelity is directly related to roost permanence (Lewis 1995). The same may also be true of *N. major*.

In a study of roost use by bats in Tasmania, Taylor &

Savva (1988) noted that *N. geoffroyi* change roosts frequently. They located two roosts under bark, one in a narrow cavity in a tree bole, and one in a fissure. However, unlike this study, *N. geoffroyi* were only found roosting in a dead tree once. In remnant vegetation around farmland in Victoria, *N. geoffroyi* were found to roost disproportionately in dead trees, a finding similar to that reported here (L Lumsden, *pers. comm.*).

The preference that *N. geoffroyi* displayed for dead *Banksia* trees over live *Melaleuca* trees, during this study, probably relates to different winter thermal characteristics of roosts found in the two tree species. By choosing *Banksia* roosts, *N. geoffroyi* are exposed to temperatures above ambient during the late afternoon and this would reduce the costs of arousal from torpor prior to foraging. It was noted that many roosts in *Banksia* trees were facing the afternoon sun and this may explain why  $T_r$  was higher than  $T_a$  in the afternoon in *Banksia* tree roosts. In addition, dead *Banksia* trees were dark coloured, which presumably aids heating further. If the same thermal characteristics are found during summer, it is reasonable to expect *Melaleuca* trees to be the preferred roost. With their apparently superior insulation, *Melaleuca* would be cooler than *Banksia* roosts; low temperatures enable bats to lower their body temperature, leading to water and energy savings (*e.g.* Hosken & Withers in press). That *N. major* were found to

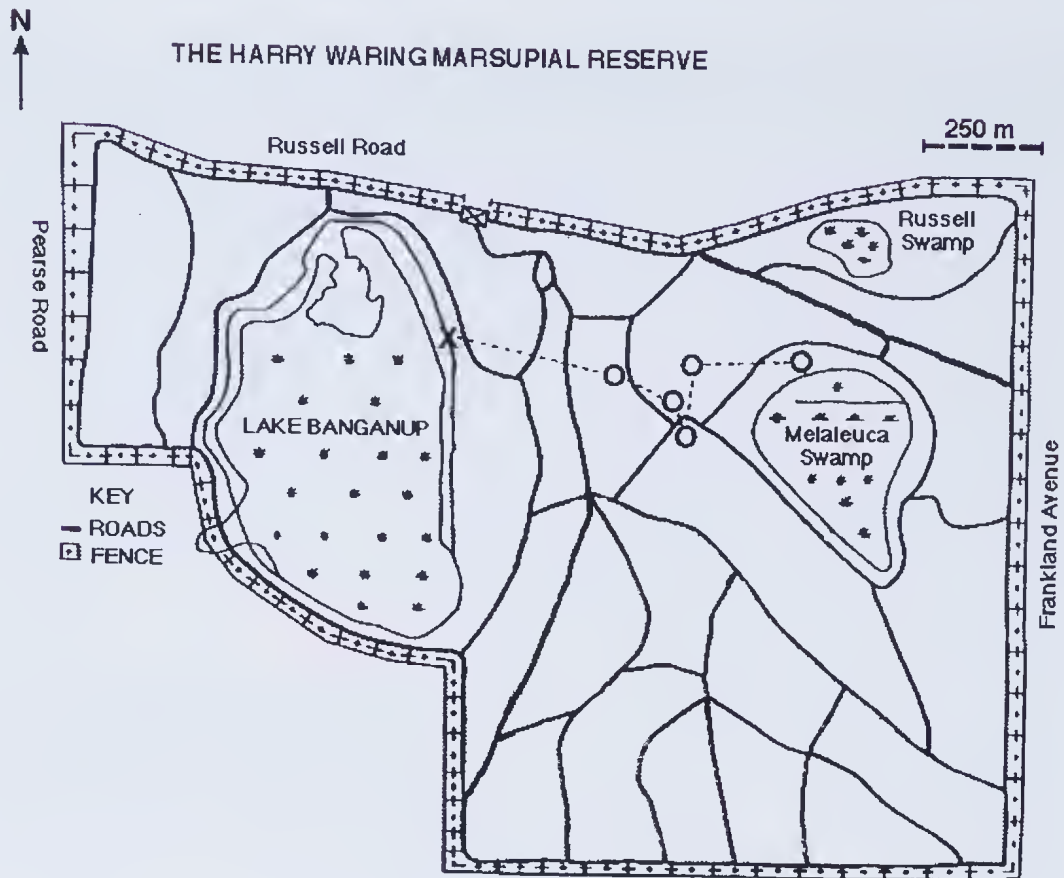


Figure 2. Map of the Harry Waring Marsupial Reserve showing the roost movement patterns of a female *N. geoffroyi*. x = site of capture, o = roost locations, dotted lines show bat movement between roosts.

frequently use these trees during summer appears to support this reasoning, but further investigation is required. No bats were found roosting in live *Banksia* trees. This is probably due to the fact that the bark is not loose on live trees and further indicates that *N. geoffroyi* are selecting specific roost sites.

The use of *Melaleuca* roosts during rainy periods probably relates to the fact that these trees are not water harvesting, and roosts under the multilayered bark insulation stay dry, while roosts in dead *Banksia* trees were often damp during and after rain. In addition, storms appear to exact a heavier toll on dead *Banksia* trees when compared with *Melaleuca* trees; four dead *Banksia* trees were found across tracks after storms during the course of the study. This also indicates that the *Banksia* roosts are relatively ephemeral, which makes the reliance on one roost unprofitable and possibly prompts frequent roost movement. All trees that were found to contain roosts during this study were tagged and longer term observation will reveal the longevity of each roost.

In this study, *N. geoffroyi* were found to roost alone. This is consistent with other published reports (Lumsden & Bennett 1995, Taylor & Savva 1988). However, Taylor & Savva (1988) also found three colonies containing three, 12 and 23 *N. geoffroyi*. The two largest groups were maternity colonies. Since this study was carried out during autumn and winter, no maternity colonies were

encountered and it appears that these bats, at least in *Banksia* woodland, are solitary during the mating period which extends from about April to September (Hosken, unpublished data).

As with *N. gouldi* (Lunney *et al.* 1988), *N. geoffroyi* appear to display fidelity to an area and the distances between successive roosts reported here are similar to those reported for other nyctophilines (Lunney *et al.* 1988, 1995). The largest distance between capture site and roost site for *N. geoffroyi* in this study was about 1200m. This is similar to the distances moved by male *N. geoffroyi* in Victoria (L Lumsden *pers. comm.*) but less than the 4800m reported by Taylor and Savva (1988) and the 6–12km reported for female *N. geoffroyi* (L Lumsden *pers. comm.*). However, the comparatively small distances between capture site and roost site reported here are consistent with the flight morphology of *N. geoffroyi* which indicates that this species is not suited to long distance flight (Fullard *et al.* 1991). A similar finding is reported here for *N. major*. The only individual which regularly changed roosts during this study was found to move about the same distance as the *N. geoffroyi*. This *N. major* shed its transmitter at its initial capture site five days after capture. This was approximately 1200m from its last roost tree. *N. major* is reported to have flight characteristics similar to *N. geoffroyi* (Hall & Richards 1979), which suggests that long distance flight would also be energetically expensive for this species.

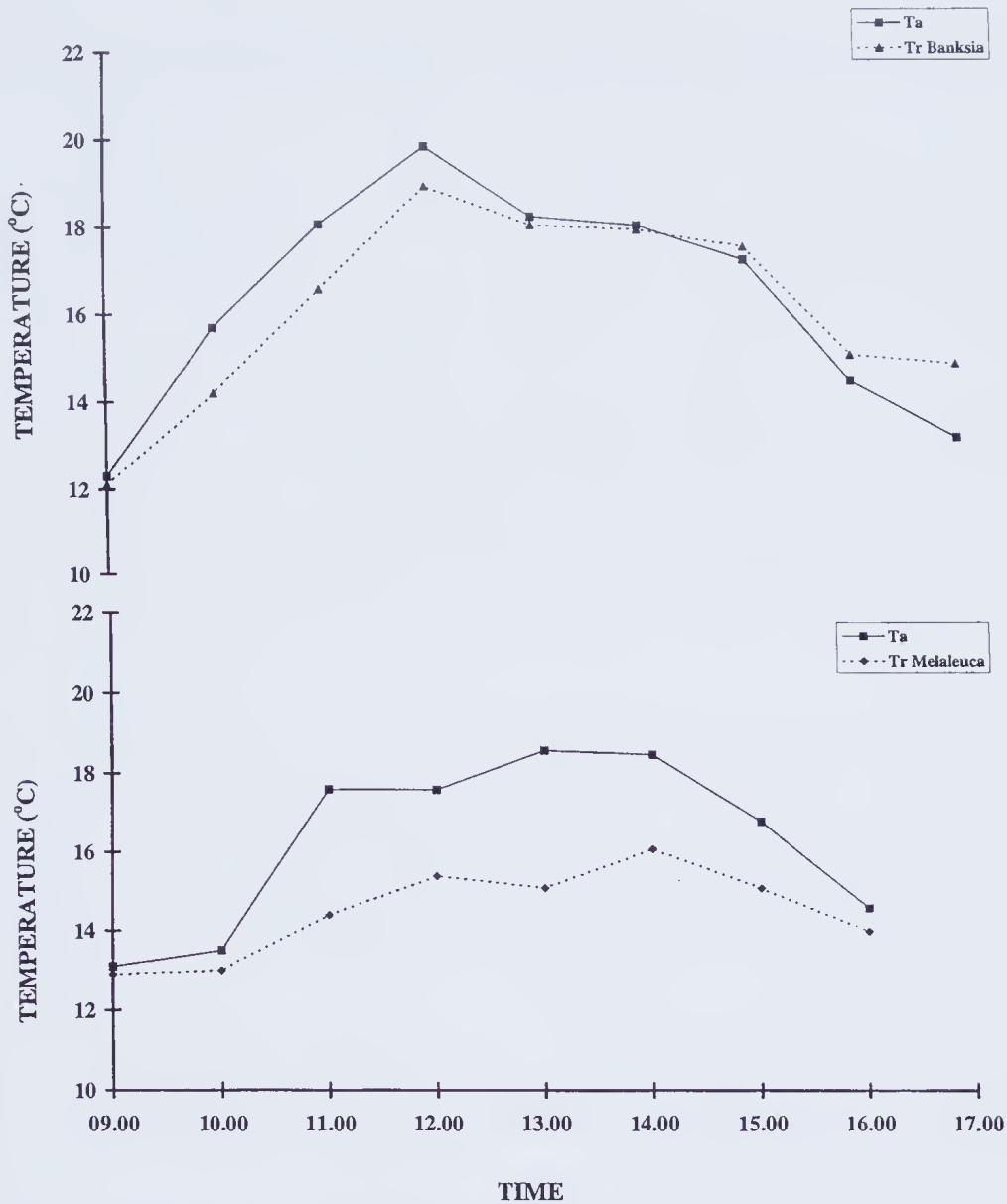


Figure 3. Hourly changes in the roost temperature of a typical *Banksia* roost (top) and a typical *Melaleuca* roost (bottom) plotted with  $T_a$  measured outside but adjacent to the roost.

The use of only large mature or dead trees by both the bat species tracked during this study indicates that a mature forest is essential for them. The finding that dead trees were the predominant roost used by *N. geoffroyi* and that these trees appear to be the main victims of winter storm indicates that the continual tree death is required to maintain the roosts needed by these small bats. Unfortunately, continued clearing on the Swan Coastal Plain may eventually threaten this continuity.

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### References

- Fullard J H, Koehler C, Surlykke A & McKenzie N L 1991 Echolocation ecology and flight morphology of insectivorous bats (Chiroptera) in south-western Australia. *Australian Journal of Zoology* 39:427-438.
- Grant J D A 1991 Prey location by two Australian long-eared bats, *Nyctophilus gouldi* and *N. geoffroyi*. *Australian Journal of Zoology* 39:45-56.
- Hall L S & Richards G C 1979 Bats of eastern Australia. Queensland Museum, Brisbane, Booklet No. 12.
- Hosken D J & O'Shea J E 1995 *Falsistrellus mackenziei* at Jandakot. *The Western Australian Naturalist* 19:351.
- Hosken D J & Withers P C in press Temperature regulation and metabolism of an Australian bat, *Chalinolobus gouldii* (Chiroptera: Vespertilionidae) when euthermic and torpid. *Journal of Comparative Physiology B*: in press.
- Hosken D J, Bailey W J, O'Shea J E & Roberts J D 1994 Localisation of insect calls by the bat *Nyctophilus geoffroyi* (Chiroptera: Vespertilionidae): a laboratory study. *Australian Journal of Zoology* 42:177-184.

- Kunz T H 1982 The roosting ecology of bats. In: Ecology of Bats (ed TH Kunz) Plenum Press, New York, 1-55.
- Lewis S E 1995 Roost fidelity of bats: a review. *Journal of Mammalogy* 76:481-496.
- Lumsden L F & Bennett A F 1995 Lesser long-eared bat. In: Mammals of Victoria: distribution, ecology and conservation (ed PW Monkhorst) Oxford University Press, Melbourne, 184-186.
- Lunney D, Barker J, Priddel D & O'Connell M 1988 Roost selection by Gould's long-eared bat, *Nyctophilus gouldi* Tomes (Chiroptera: Vespertilionidae), in logged forest on the south coast of New South Wales. *Australian Wildlife Research* 15:375-384.
- Lunney D, Barker J, Leary T, Priddel D, Wheeler R, O'Connor P & Law B 1995 Roost selection by the north Queensland long-eared bat *Nyctophilus bifax* in littoral rainforest in the Iluka World Heritage Area, New South Wales. *Australian Journal of Ecology* 20:532-537.
- Parnaby, H 1995 Greater long-eared bat. In: The Mammals of Australia 2<sup>nd</sup> edition (ed R Strahan) Reed Books, Chatswood, 507-508.
- Reardon T B & Flavel S C 1987 A guide to the bats of South Australia. South Australian Museum, Adelaide.
- Richards G C 1991 Greater long-eared bat. In: The Australian Museum Complete Book of Australian Mammals 3<sup>rd</sup> edition (ed R Strahan) Cornstalk Publishing, North Ryde, 328.
- Taylor R J & Savva N M 1988 Use of roost sites by four species of bats in State Forest in south-eastern Tasmania. *Australian Wildlife Research* 15:637-645.
- Vestjen W & Hall L 1977 Stomach contents of 42 species of bats from the Australasian region. *Australian Wildlife Research* 4:25-35.